

ENDNOTES

- 1 Human-caused emissions of sulphate aerosols (produced by burning high sulfur coal) have to-date likely offset a substantial fraction of greenhouse warming by reflecting sunlight back to space. While greenhouse gases are well-mixed in the atmosphere with typical lifetimes of decades to centuries, sulphate aerosols from human-caused emissions have typical lifetimes of one to a few weeks, and they are localized around their source regions. Ironically, future clean-up of air pollution around major industrial regions will likely reduce the cooling effects of aerosols and result in a faster rate of climate warming.
- 2 Prentice, I.C., et al. 2001. The carbon cycle and atmospheric carbon dioxide. In J. T. Houghton et al. (eds.), *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: pp. 183-238.
- 3 Folland, C.K. et al. 2001. Observed climate variability and change. In J. T. Houghton et al. (eds.), *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: pp. 99-182.
- 4 Prentice et al. 2001
- 5 Prather, M., D. Ehhalt, and others. 2001. Atmospheric chemistry and greenhouse gases. In J. T. Houghton et al. (eds.), *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: pp. 239-288.
- 6 Such projections are made after considering a range of possible future human development scenarios and resultant greenhouse gas concentrations, and feeding those greenhouse gas concentrations into global climate models. Climate models apply the laws of physics to the atmosphere, ocean, and land surface. They have been demonstrated to simulate 20th century climate quite well, including the observed trends in temperature. Cubasch, U. et al. 2001. Projections of Future Climate Change. In J. T. Houghton et al. (eds.), *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: pp. 525-582.
- 7 Church, J.A. et al. 2001. Changes in sea level. In J. T. Houghton et al. (eds.), *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press: pp. 639-693.
- 8 Mote, P.W. 2003a. Twentieth-century fluctuations and trends in temperature, precipitation, and mountain snowpack in the Puget Sound/Georgia Basin region. *Canadian Water Resources Journal* 28:567-586.
- 9 These trends cancel out globally when the trends in different regions are averaged together.
- 10 Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78:1069-1079. More information on the PDO, and up-to-date values for the time series, can be found at <http://jisao.washington.edu/pdo/>
- 11 Mote 2003a
- 12 Using statistical techniques, researchers have determined that greenhouse gases have almost certainly contributed to the warming of the 20th century on scales from 1000 miles or so to global. However, determining this at the scale of Puget Sound is not yet possible: thus, any changes described in this document cannot unequivocally be attributed to human influence on global climate.
- 13 Easterling, D.R., T.R. Karl, K.P. Gallo, D.A. Robinson, K.E. Trenberth, and A. Dai. 2000. Observed climate variability and change of relevance to the biosphere. *Journal of Geophysical Research* 105(D15): 20,101-20,114.
- 14 These temperature and precipitation projections were downscaled for the Pacific Northwest from climate model simulations prepared for the fourth IPCC assessment report, due out in 2007.
- 15 Cayan, D.R., S.A. Kammerdiener, M.D. Dettinger, J.M. Caprio, and D.H. Peterson. 2001. Changes in the onset of spring in the western United States. *Bulletin of the American Meteorological Society* 82:399-415; Mote, P.W., A.F. Hamlet, M. Clark, and D.P. Lettenmaier. 2005a. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society* 86(1):39-49. Regonda, S.K., B. Rajagopalan, M. Clark, and J. Pitlick. 2005. Seasonal cycle shifts in hydroclimatology over the western United States. *Journal of Climate* 18:372-384; Stewart, I.T., D.R. Cayan, and M.D. Dettinger. 2005. Changes toward earlier streamflow timing across western North America. *Journal of Climate* 18:1136-1155.
- 16 Mote et al. 2005a; Cayan et al. 2001; Stewart et al. 2005; Hamlet, A.F., P.W. Mote, M. Clark, and D.P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western U.S. *Journal of Climate*, in press.
- 17 Mote, P.W. 2003b. Trends in snow water equivalent in the Pacific Northwest and their climatic causes. *Geophysical Research Letters* 30(12) 1601, doi:10.1029/2003GL017258, 2003.
- 18 In descending order of volume, they are the Snohomish, Puyallup, Nooksack, Nisqually, Green, Stillaguamish, Skokomish, Cedar, Deschutes, Samish, and Duckabush. The Skagit is omitted even though it is the largest because of the effects on flow of the operation of Ross and Diablo dams for hydropower. The Nisqually, Deschutes and Samish are omitted because of incomplete flow records.
- 19 As indicated by the midpoint of water year flow, that is, the date at which half the flow between 10/1 and 9/30 has occurred. In snowmelt-dominated basins this occurs much later than the midpoint of precipitation; for the mean inflow to Puget Sound, the midpoint typically occurs in March.
- 20 Mote, P.W., A.K. Snover, L. Whitely Binder, A. F. Hamlet, and N. J. Mantua. 2005b. *Uncertain Future: Climate Change and its Effects on Puget Sound, Foundation Document*. A report for the Puget Sound Action Team by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle).
- 21 A portion of the observed trends is probably due to reservoir management and changing land use, which were not corrected for in this analysis.
- 22 A. Fountain (Portland State University) pers. comm.
- 23 Miles, E. L., A. K. Snover, A. F. Hamlet, B. M. Callahan, and D. L. Fluharty. 2000. Pacific Northwest regional assessment: The impacts of climate variability and climate change on the water resources of the Columbia River Basin. *Journal of the American Water Resources Association* 36(2):399-420; Mote, P.W., E. A. Parson, A. F. Hamlet, K. N. Ideker, W. S. Keeton, D. P. Lettenmaier, N. J. Mantua, E. L. Miles, D. W. Peterson, D. L. Peterson, R. Slaughter, and A. K. Snover. 2003. Preparing for climate change: The water, salmon, and forests of the Pacific Northwest. *Climatic Change* 61:45-88.
- 24 Mote, P.W., M. Holmberg, N. J. Mantua, and Climate Impacts Group. 1999. *Impacts of Climate Variability and Change, Pacific Northwest*. National Atmospheric and Oceanic Administration, Office of Global Programs, and JISAO/SMA Climate Impacts Group, Seattle, Washington. 110 pp.
- 25 Church et al. 2001
- 26 Holdahl, S. R., F. Faucher, and H. Dragert. 1989. Contemporary vertical crustal motion in the Pacific Northwest. In S.C. Cohen and P. Vanicek (eds.), *Slow Deformation and Transmission of Stress in the Earth*. Washington, D.C.: American Geophysical Union, Geophysical Monograph, Volume 49; Mofield, H.O. 1989. Long-term trends and interannual variations of sea level in the Pacific Northwest region of the United States, pp. 228-230. In *Oceans '89: An international conference addressing methods for understanding the global ocean, September 18-21, 1989, Seattle, Washington*. IEEE Publication No. CH2780-5. Piscataway, New Jersey: IEEE Service Center; Shipman, H. 1989. *Vertical Land Movements in Coastal Washington: Implications for Relative Sea Level Changes*. Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Washington.
- 27 Canning, D.J. 1991. *Sea Level Rise in Washington State: State-of-the-Knowledge, Impacts, and Potential Policy Issues*. Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Washington.
- 28 The range of values given for future sea level change reflects uncertainty about the sensitivity of the earth's climate to increased greenhouse gas concentrations, in particular uncertainty in the future behavior of the Antarctic ice sheet, and how greenhouse gas emissions will change in the future. Church et al. 2001
- 29 Hengeveld, H. G. 2000. *Projections for Canada's Climate Future*. Climate Change Digest CCD 00-01. Meteorological Service of Canada, Environment Canada, Downsview, Ontario.
- 30 Pinnix, W.D. 1999. Marine survival of Puget Sound coho salmon: deciphering the climate signal. M.S. Thesis, University of Washington, Seattle (summarizing Ebbsmeyer, C.C., and C.A. Barnes. 1980. Control of a fjord basin's dynamics by tidal mixing in embracing sill zones. *Estuarine and Coastal Marine Science* 2:310-330; Ebbsmeyer, C.C., C.A. Coomes, G.A. Cannon, and D.E. Bretschneider. 1989. Linkage of ocean and fjord dynamics at decadal period. *Geophysical Monograph* 55:399-417.
- 31 Ebbsmeyer et al. 1989
- 32 Newton, J.A., E. Siegel, and S.L. Albertson. 2003. Oceanographic changes in Puget Sound and the Strait of Juan de Fuca during the 2000-01 drought. *Canadian Water Resources Journal* 28(4):715-728.
- 33 www.prism.washington.edu
- 34 Mote, P.W. and N.J. Mantua. 2002. Coastal upwelling in a warmer future. *Geophysical Research Letters* 29(23):53-1-53-4.

- 35 Murdoch, Peter S., J.S. Baron, and T.L. Miller. 2000. Potential effects of climate change on surface-water quality in North America. *Journal of the American Water Resources Association* 36(2):347-366.
- 36 (PSAT 2004) Puget Sound Action Team. 2004. *State of the Sound 2004*. Puget Sound Action Team, Office of the Governor, Olympia, Washington.
- 37 Arhonditsis, G.B. et al. 2004. Effects of climatic variability on the thermal properties of Lake Washington. *Limnology and Oceanography* 49(1):256-270.
- 38 Strom, A., R. C. Francis, N. J. Mantua, E. L. Miles, and D. L. Peterson. 2004. North Pacific climate recorded in growth rings of geoduck clams: A new tool for paleoenvironmental reconstruction. *Geophysical Research Letters* 31, doi: 10.1029/2004GL019440.
- 39 Newton, J.A., S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel. 2002. Washington State Marine Water Quality, 1998 through 2000. Publication No. 02-03-056, Washington Department of Ecology, Lacey, Washington. (www.ecy.wa.gov/biblio/0203056.html)
- 40 Newton et al. 2002
- 41 Newton et al. 2003
- 42 Newton et al. 2002
- 43 Newton et al. 2002
- 44 Newton et al. 2003
- 45 Free oxygen is available for chemical reactions, not bound up tightly with molecules like water.
- 46 Newton et al. 2002
- 47 Newton et al. 2002
- 48 (PSWQAT 2002) Puget Sound Water Quality Action Team. 2002. 2002 Puget Sound Update: Eighth Report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Action Team, Olympia, Washington.
- 49 PSWQAT 2002
- 50 http://www.ecy.wa.gov/programs/eap/mar_wat/eutrophication.html
- 51 PSAT 2004
- 52 Newton et al. 2002
- 53 Hare, S.R., and N.J. Mantua. 2000. Empirical evidence for North Pacific regime shifts in 1977 and 1989. *Progress in Oceanography* 47:103-145.
- 54 Mantua et al. 1997
- 55 Nichols, F.H. 2002. Is climate change a factor in observed interdecadal change in the deep Puget Sound benthos? In *Proceedings of the 2001 Puget Sound Research Conference*. T. Droscher (ed.). Puget Sound Action Team. Olympia, Washington.
- 56 Li, M., A. Gargett, and K. Denman. 2000. What determines seasonal and interannual variability of phytoplankton and zooplankton in strongly estuarine systems? Application to the semi-enclosed estuary of Strait of Georgia and Juan de Fuca Strait. *Estuarine Coastal and Shelf Science* 50(4):467-488.
- 57 Thom, R.M., A.B. Borde, S.L. Blanton, D.L. Woodruff, and G.D. Williams. 2001a. The influence of climate variation and change on structure and processes in nearshore vegetated communities of Puget Sound and other Northwest estuaries. In Puget Sound Action Team, T. Droscher (ed.), *Proceedings of the 2001 Puget Sound Research Conference*. Puget Sound Action Team. Olympia, Washington.
- 58 Thom et al. 2001a
- 59 Feely, R.A. et al. 2004. Impact of anthropogenic CO₂ on the CaCO₃ system in the oceans. *Science* 305:362-366.
- 60 Arhonditsis et al. 2004
- 61 Winder, M., and D. E. Schindler. 2004a. Climatic effects on the phenology of lake processes. *Global Change Biology* 10:1844-1856.
- 62 Winder, M., and D. E. Schindler. 2004a. Climate change uncouples trophic interactions in a lake ecosystem. *Ecology* 85:2100-2106.
- 63 (PSAT 2003) Puget Sound Action Team. 2003. Treasures of the Tidelands: Shellfish Economy (Fact sheet). Puget Sound Action Team, Office of the Governor, Olympia, Washington.
- 64 Trainer, V., B.L. Eberhart, J.C. Wekell, N.G. Adams, L. Hanson, F. Cox, and J. Dowell. 2003. Paralytic shellfish toxins in Puget Sound, Washington State. *Journal of Shellfish Research* 22(1):213-223.
- 65 Trainer et al. 2003
- 66 (Ecology 2005) Washington Department of Ecology. 2005. Puget Sound Shorelines: Salmon. www.ecy.wa.gov/programs/sea/pugetsound/species/salmon.html (accessed 01/05/05)
- 67 Thom R.M. 1992. Accretion rates of low intertidal salt marshes in the Pacific Northwest. *Wetlands* 12(3):147-156.
- 68 Adam, P. 2002. Salt marshes in a time of change. *Environmental Conservation* 29(1):39-61; Hughes, R.G. 2004. Climate change and loss of saltmarshes: Consequences for birds. *Ibis* 146 (Suppl. 1):21-28; Titus, J. G. 1986. Greenhouse effect, sea level rise, and coastal zone management. *Coastal Zone Management Journal* 14(3):147-171.
- 69 Thom et al. 2001a
- 70 (PSWQAT 2001) Puget Sound Water Quality Action Team. 2001. *Eelgrass (Zostera marina)*. (Fact sheet), October 2001.
- 71 Light availability, wave and current energy, nutrient availability, and substrate composition also affect eelgrass growth. Thom, R.M., A.B. Borde, G.D. Williams, J.A. Southward, S.L. Blanto, and D.L. Woodruff. 2001b. Effects of multiple stressors on eelgrass restoration projects. In Puget Sound Action Team, T. Droscher (ed.), *Proceedings of the 2001 Puget Sound Research Conference*. Puget Sound Action Team. Olympia, Washington; Thom, R.M., A.B. Borde, S. Rumrill, D.L. Woodruff, G.D. Williams, J.A. Southard, and S.L. Sargeant. 2003. Factors influencing spatial and annual variability in eelgrass (*Zostera marina* L.) meadows in Willapa Bay, Washington, and Coos Bay, Oregon, estuaries. *Estuaries* 26(4B):1117-1129.
- 72 Thom et al. 2003
- 73 Thom et al. 2003
- 74 Thom et al. 2001a
- 75 Boesch, D.F., J.C. Field, and D. Scavia (eds.). 2000. The Potential Consequences of Climate Variability and Change on Coastal Areas and Marine Resources: Report of the Coastal Areas and Marine Resources Sector Team, U.S. National Assessment of the Potential Consequences of Climate Variability and Change, U.S. Global Change Research Program. NOAA Coastal Ocean Program Decision Analysis Series No. 21. NOAA Coastal Ocean Program, Silver Spring, Maryland. 163 pp.
- 76 (HEED 1998) Health Ecological and Economic Dimensions. 1998. *Marine Ecosystems: Emerging Diseases as Indicators of Global Change*. Year of the Ocean Special Report on Health of the Oceans from Labrador to Venezuela. NOAA Office of Global Programs and National Aeronautics and Space Administration. HEED 1998 cited in Boesch et al. 2000; Harvell C.D., et al. 1999. Emerging marine diseases: Climate links and anthropogenic factors. *Science* 285:1505-1510.
- 77 McCullough, D. A. 1999. *A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Region 10 Water Resources Assessment Report No. 910-R-99-010. United States Environmental Protection Agency, Seattle, Washington.
- 78 F. Goetz, US Army Corps of Engineers, pers. comm.
- 79 <http://wdfw.wa.gov/fish/chum/>. The four summer-run stocks of chum salmon in Hood Canal and the Strait of Juan de Fuca have been listed as "threatened" under the Endangered Species Act; a notable exception to the otherwise positive picture for Puget Sound chum salmon.
- 80 <http://www.hoodcanal.washington.edu/>
- 81 Canning 1991.
- 82 Winder and Schindler 2004a. Updated data provided by Monika Winder.